**The Impact of Referee Decisions on Football Match Outcomes**

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**Abstract**

Football referees play a crucial role in ensuring all rules are followed and fair play is practiced. Unfortunately, they can also use their powers to influence outcomes of games. There have always been shady stories in which referees favor certain sides, and with the 2022 World Cup in Qatar having some of the most controversial calls in the sport’s history, our team wanted to explore the extent of these biases. We investigated the English Premier League’s referees and their decisions, including fouls, penalties, red cards, and yellow cards and the consequential outcomes, such as half-time and full-time goals scored. More specifically, our analysis of nearly every game played from 2014-2015 to 2018-2019 sought to answer three questions. (1). Is there a difference between the number of fouls, yellow cards, and red cards booked against the Big 6 relative to other teams? (2). Which referees display bias towards certain teams? (3). Which teams are most likely to have fouls, yellow cards, and red cards booked against them? Our findings saw that certain referees may have negative biases, and certain teams have more/less calls than others on average, but it is difficult to definitively conclude any biases, as many other variables besides referee calls can also sway the outcome of games.

*Keywords:* Bias, outcome, yellow card, red card, fouls, penalties, goals, referees

**Exploration:**

* **Correlation**
* **Red and yellow**
* **Alex**
* **Away vs home:yellow**
* **Red card h vs a**
* **Yellow card vs fouls**
* **Bar plot of fouls and yellow cards**

In our analysis of the English Premier League (EPL), we focused on two separate areas: the relationship between half-time and full-time goal counts and the number of yellow cards issued by each referee to the home and away teams. Initially, we created a catalog of qualified referees who had officiated in at least 20 games over the five seasons we considered. We then filtered the 'epl\_data' data frame, retaining only the games officiated by these qualified referees, and performed exploratory analysis on the relationship among the half-time and full-time goal counts for both home and away teams.

Our analysis showed that, apart from the correlation between half-time home goals (HTHG) vs full-time home goals (FTHG) and half-time away goals (HTAG) vs full-time away goals (FTAG), there was no significant correlation among other variables. The correlation coefficient for the former comparison was 0.7, and the scatter plot demonstrated that when a team scored more goals in the first half, they were more likely to maintain their lead and win the game.

Moving on to the second area of focus, we computed the number of yellow cards given to both teams by each referee and created a heat map to show the ratio of cards given to the home team vs the total number of cards in a game by each referee. We split the data into two groups - 'home\_cards' and 'away\_cards' - and created a single data frame, 'all\_cards,' that included the total number of cards given to each team by each referee. We created a new variable to represent the total number of cards given to each team by all referees and calculated the percentage of cards given to the home team by each referee. The heat map created for Manchester United revealed a significant difference between the referees.

Our analysis suggests that referees' decisions can impact the outcome of games, with a team that is consistently given more yellow cards than their opponents facing a potential disadvantage. However, note that our analysis only considered yellow cards and did not include other factors that could affect the game's outcome, such as red cards, penalties, or injuries. Furthermore, there may be lurking variables that could affect the results. Despite these limitations, the heat map gives an accurate picture of which referees tend to give more yellow cards to home teams, providing valuable information for future research.

Furthermore, we also looked at data about yellow and red cards given out by referees in the English Premier League (EPL). We chose the information we needed and made two separate lists, one for yellow cards given to the home team and one for yellow cards given to the away team. We combined these two lists to make a single list of all the yellow cards given out. We also did the same thing for red cards. We used this data to make a graph showing which referees gave out the most and least yellow and red cards to home and away teams.

Our analysis shows that Phil Dowd gave the most yellow cards overall, and Mike Dean gave the most red cards to away teams. In addition, the referees who gave out the least number of cards were Paul Tierney for red cards to away teams, and Mike Jones for red cards to home teams.

We made a box plot to compare how often referees give out yellow cards in the English Premier League. This helps us see if there are any patterns in how referees make decisions. We looked at data for each referee, which included information about how many yellow cards and fouls happened in each game. We calculated a ratio of yellow cards to fouls for each referee and used this to create the box plot. We found that most referees gave out yellow cards less often than average, which might mean that players were committing fewer fouls or less serious fouls. The referee with the highest percentage of yellow cards was Mike Dean, and the referee with the lowest was Paul Tierney. We also noticed one referee, Neil Swarbick, had an extreme outlier value. This could mean he was officiating games with more fouls.

To check if referees have a bias towards home teams in calling fouls, a study selected 20 referees and compared the number of fouls they gave to home and away teams. Most referees gave around 10 fouls, with P. Dowd giving the most and A. Marrier giving the least. The analysis suggested that referees tend to give more fouls to the home team. 15 referees gave more fouls to the home team than the away team, indicating a possible bias. However, it's important to keep in mind that other factors such as player skills and luck also play a role in game outcomes. It's also important to investigate if this trend exists in other sports and regions.

**Questions:**

* Is there a difference between the number of fouls, yellow cards, and red cards booked against the Big 6 relative to other teams?
  + Population calculations
  + Rainbow box plot
* Which referees display bias towards certain teams?
  + Q2 graphs
* Which teams are most likely to have fouls, yellow cards, and red cards booked against them?
  + Q3 graphs

**Introduction**

Refereeing decisions have always been an important part of football since they are responsible for enforcing the rules and ensuring fair play. However, there are instances where the decisions made by referees can impact the outcome of the game. Over the years, there has been a lot of debate about the impact that referees can have on the outcome of a match. Especially with the recent World Cup, this debate has been heightened, with some high-profile incidents leading to controversy and calls for changes to the way that referees are selected, trained, and evaluated.

One way in which referees can affect the outcome of a football game is through their interpretation of the rules. Referees have a certain amount of discretion when it comes to enforcing the laws of the game, and their interpretations can sometimes be subjective. For example, a referee may choose to overlook a minor foul committed by a player, while another referee may consider it to be a more serious offense and award a free kick or even a penalty kick. These decisions can have a significant impact on the game since a free kick or penalty kick can change the momentum and ultimately the outcome of the match.

Another way in which referees can affect the outcome of the game is through their mistakes. Referees are human, and they can make mistakes in judgment or miss critical incidents during the game. However, these mistakes can also have a significant impact on the match’s outcome. In some cases, a referee’s mistake can result in a goal being awarded to the wrong team or a crucial penalty being overlooked, which can lead to an unfair advantage for one team over the other.

There are a lot of ways in which referees can have a significant impact on the outcome of the game. Therefore, our group wanted to focus on the 2014-2019 seasons of the English Premier League and analyze the impact the referees had for those two seasons. In order to do this, we collected and integrated five datasets containing various information about the matches, including the match results, player statistics, and referee performance.We then compared the frequency of each referee giving out yellow and red cards, fouls, free kicks, etc. to determine how the referees have an impact on the outcome of premier league matches. Our main objective for this project was to determine referee biases and the amount of impact they put on the outcome of games.

**Data & Methods | Results | Discussion**

**```{r}**

Initially, we generated a catalog of referees who had officiated in 20 or more games during the five seasons under consideration. Next, we performed filtering of the 'epl\_data' data frame, that we used throughout our analysis, keeping only the games that were presided over by the previously identified qualified referees. We conducted an exploratory analysis of the relationship among the half-time and full-time goal counts for both the home and away teams.

The analysis revealed that, with the exception of the correlation between Half-Time Home Goal (HTHG) vs Full-Time Home Goal (FTHG) and Half-Time Away Goal(HTAG) vs Full-Time Away Goal (FTAG), there was no significant correlation among the other variables. The correlation coefficient for the aforementioned comparison was 0.7. Also, the scatterplot supports this idea; as the values of HTAG increase, the values for FTAG also increase. This suggests that when a team scores more goals in the first half, it is more likely to maintain their lead and win the game.

**```{r april 1} & ```{r red and yellow}**

In the next phase of the study, we created a dataset for the referees' cards from the 'epl\_data' data frame and calculated the expected value of yellow and red cards given per game. This approach enabled us to compare the disciplinary actions of different referees and identify potential trends or biases in their decision-making.

The resulting chart showed that the frequency of yellow cards was notably higher than that of red cards per game. The bars for yellow cards clustered around 3, with P. Dowd having the highest average of 4.38 and the lowest being 2.4. For red cards, none of the referees exceeded a threshold of 0.2 red cards per game, except for L. Probert and M. Dean, whose values were 0.21 and 0.23, respectively. This suggests a relative consistency in disciplinary actions across referees.

It's worth noting that the expected value of data for yellow cards is less variable than that for red cards. This may be due to the fact that yellow cards are more frequent, i.e., there is a larger sample size, which possibly explains why the trends in red cards show the referees' bias more than the data from yellow cards since red cards can directly impact the outcome of a game.

Overall, the study provides valuable insights into the referees' decision-making in the context of issuing yellow and red cards in sports. The results can inform discussions about the fairness and transparency of sports competitions and the need for measures to ensure that referees are objective and impartial in their disciplinary actions.

**```{r alex}**

Here, we computed the number of yellow cards given to both teams by each referee, and a heat map is created to show the ratio of cards given to the home team vs total cards in a game by each referee.

The data is split into two groups: ‘home\_cards’ and ‘away\_cards’. These variables represent yellow cards given to the home and away teams, respectively. These groups are combined to create a single data frame, ‘all\_cards’, which includes the total number of cards given to each team by each referee. A new column is created to represent the total number of cards given to each team by all referees, and the percentage of cards given to the home team by each referee is calculated. A heat map is created for a specific home team (Manchester United) to visualize the percentage of cards given to them by each referee.

The analysis shows that the percentage of cards given to the home team varies significantly depending on the referee. The heat map gives an insight into how some referees show more tendency to give yellow cards to Manchester United than other referees. For example, the percentage of yellow cards given by Mike Dean from the 5 seasons was around 12.5%, whereas the percentage of yellow cards given by Stuart Attwell was around 0.125% The heat map shows a clear difference between the referees, with some having a higher percentage of yellow cards given to the home team, while other have a lower percentage.

The results of this analysis suggest that the referees’ decisions during football matches can impact the outcome of games. A team that is consistently given more yellow cards than their opponents may face a disadvantage during the game. However, it is worth noting that the analysis only considers yellow cards and does not include other factors that can affect the outcome of the game, such as red cards, penalties, or injuries. In addition, these percentages may be due to possible lurking variables. For example, Mike Dean could have possibly refereed for Manchester United more than Stuart Attwell and Mike Dean could have refereed rivalry matches, as rivalry matches produce more yellow cards. Further research is needed to confirm these findings but this heat map gives accurate information on which referee gives more yellow cards to home teams, Manchester United in this case.

**```{r away vs home:yellow}**

We analyzed the data on yellow cards issued by each referee in the English Premier League (EPL) for the home and away team. First, in the variable ‘card\_data’, we loaded the EPL data and selected only the relevant variables for this analysis: the home team (HomeTeam), away team (AwayTeam), referee (Referee), and the number of yellow cards issued to the home and away team (HY and AY). Then we created two separate data frames, one for home team yellow cards (home\_cards), and one for the away team yellow cards (away\_cards). For each data frame, we used a mutate function to create a new variable called ‘location’ to indicate whether the yellow card was issued to the home or away team. Then, we renamed the variables ‘HomeTeam’ and ‘AwayTeam’ to ‘team’ and the home team yellow cards (HY) and away team yellow cards (AY) to ‘cards’, respectively. After, we combined the two data frames using the rbind function to create a single data frame called ‘all\_cards’, which contains all the yellow cards issued in the matches. For the next step, we calculated the total number of yellow cards issued to each team and each referee. In order to do this, in the variable ‘team\_totals’, we grouped the data by ‘Referee’ and ‘location’ and used the summarize function to sum the ‘cards’ variable and divide it by the number of matches played (n()). Moreover, we used the filter function to filter out any referees with missing data. Next, we calculated the percentage of cards for each team and each referee by grouping the data by ‘Referee’ and ‘location’ and using the summarize function again to calculate the mean of the ‘total\_cards’ variable. This new data frame was then stored in the variable ‘card\_percentages’. Finally, we created a bar plot of the total number of yellow cards issued to home and away teams for each referee using the ggplot function. We used the variable ‘Referee’ for the x-axis and the variable ‘total\_cards’ for the y-axis. To create the bar plot, we used geom\_bar and inserted ‘stat = “identity” to plot the values as is.

From the graph, we can see that Phil Dowd gave the most yellow cards for both home and away teams. Phil Dowd gave around 2.4 yellow cards per match for the home team and 1.8 yellow cards per match for the away team. Moreover, referee Lee Probert gave the least number of yellow cards per match for the away team, which was around 1.2 yellow cards per match, and referee Graham Scott gave the least number of yellow cards per match for the home team, which was around 1.1 yellow cards per match for the home team.

**```{r red card h vs a}**

We also analyzed the data on red cards issued by each referee in the English Premier League (EPL) for the home and away team. The process was the same as the one for the yellow cards, but instead of using the variable ‘HY’ and ‘AY, we used the variable for the number of red cards issued to the home and away team (HR and AR).

From the graph, referee Mike Dean gave the most red cards for the away teams of around 0.17 red cards per match. Moreover, referee Phil Dowd gave the most red cards for the home teams of around 0.09 red cards per match. Referee that gave the least number of red cards for the away team was Paul Tierney who gave around 0.02 red cards per match while referee Mike Jones gave the least number of red cards for the home team of around 0.03 red cards per match.

**```{r yellow cards vs fouls}**

We created a box plot to compare the yellow card percentage of different referees in the English Premier League because the box plot allows for easy comparisons of yellow card percentages among different referees, potentially revealing patterns or trends in their decision-making. As a start, in the variable ‘epl\_data\_processed’, we first loaded the EPL data, grouped the data by referee (Referee), and filtered the data to remove any rows that contain missing values for the variable away team yellow cards (AY), home team yellow cards (HY), away team fouls (AF), and home team fouls (HF). After filtering the data, we used the summarize function to calculate the total number of yellow cards (AY + HY) and fouls (AF + HF) for each referee in the variable ‘Yellow’ and ‘Fouls’, respectively. The total number of yellow cards was calculated by adding the away team yellow cards and the home team yellow cards (AY + HY) while the total number of fouls was calculated by adding the away team fouls and the home team fouls (AF + HF). Then we calculated the ratio of yellow cards to fouls (Yellow / Fouls) to find the yellow card percentage and stored it in the variable ‘Ratio’. After this process, we used the ggplot function to create a boxplot of the yellow card percentage for each referee. We used the referee names (Referee) as the x-axis and the ratio (Ratio) as the y-axis. Finally, to create the boxplot, we used the geom\_boxplot function.

From the box plot, we can see that the average percentage of the yellow card for each referee is all below 0.2. The yellow card percentage being below 0.2 means that a small proportion of the fouls committed in the game resulted in a yellow card being given by the referee. In other words, it suggests that the referee had given out fewer yellow cards than average, possibly indicating that the players in the games were committing fewer fouls overall or committing fouls that were less likely to warrant a yellow card. Amongst all the referees in the English Premier League, the referee with the highest yellow card percentage was Mike Dean with 0.17 as its percentage and the referee with the lowest yellow card percentage was Paul Tierney with 0.12. There were also some outliers in the data. In particular, referee Neil Swarbick had one extreme outlier point of 0.5. In this case, the extreme value may indicate numerous possibilities. One of the possibilities could be that Neil Swarbick was officiating games with a higher number of fouls.

**```{r red cards vs fouls} :**

Similarly, we also created a box plot to compare the red card percentage of different referees in the English Premier League. In the same way, in the variable ‘epl\_data\_processed’, we first loaded the EPL data, grouped the data by referee (Referee), and filtered the data to remove any rows that contain missing values for the variable away team red cards (AR), home team red cards (HR), away team fouls (AF), and home team fouls (HF). Then we utilized the summarize function to calculate the total number of red cards and fouls for each referee in the variable ‘Red’ and ‘Fouls’, respectively. In the same way as how we calculated the total number of yellow cards, we calculated the total number of red cards by adding the away team red cards and home team red cards (AR + HR). In addition, the same formula was used to calculate the total number of fouls, which was by adding the away team fouls and home team fouls (AF + HF). The red card percentage was then calculated as the ratio of red cards to fouls (Red / Fouls) into the variable called ‘Ratio’. Again, we used the ggplot function to create a box plot of the red card percentage for each referee with the referee names (Referee) being the x-axis and the ratio (Ratio) being the y-axis.

**```{r bar plot of fouls and yellow cards}**

To investigate whether there was evidence of a "home advantage" bias among referees in the context of calling fouls in sports. To achieve this goal, a sample of 20 referees was selected, and their average frequency of calling fouls for home and away teams was calculated and analyzed.

It was observed that most of the fouls given by referees were around 10. The highest frequency of fouls given by a single referee was attributed to P. Dowd, while the lowest frequency was recorded for A. Marrier. The overall trend in the data showed that referees tend to give more fouls to the home team. In fact, 15 of the referees gave more fouls to the home team than the away team, suggesting that there may be a bias towards the home team.

However, it's important to note that the frequency of fouls given does not necessarily determine the outcome of a game. Other factors such as team performance, player skill, and luck can also play a significant role. Additionally, it's worth exploring further to determine whether the trend of giving more fouls to the home team is consistent across different leagues, sports, and regions.

**```{r yellow cards freq } & ```{r red card freq}**

In the Premier League, big 6 (Manchester United, Manchester City, Chelsea, Liverpool, Tottenham, and Arsenal) teams are known for their larger stadium, larger number of seating capacity, and thus larger number of fans supporting in their home game. To see whether the crowd affects the ‘home advantage’, i.e. referees’ decision of calling yellow/red cards compared to the number of fouls big 6 makes. We created a dataset for the big 6 and other 6 teams(bad 6) which are usually in the relegation zone and relatively have a lower number of fan base. We calculated the overall median of fouls and compared the ratio of yellow/red cards to fouls in their home games. Then, we made a horizontal line for the average of median ratio of EPL.

The plot for the ratio of yellow cards to fouls showed that bad 6 teams generally receive more yellow cards when committing fouls at home games compared to big 6 teams. Four out of the six bad 6 teams had a median ratio of yellow cards to fouls above the horizontal line indicating the average median ratio of EPL, while only Arsenal of the big 6 had a median ratio above the line. This suggests that the crowd could influence referees' decisions to issue yellow cards, with less popular teams more likely to receive them.

Additionally, the plot for the ratio of red cards to fouls showed that the median ratio for both big 6 and bad 6 teams was approximately zero. This implies that it is challenging to get a red card unless a player makes a severe foul, such as a tackle in the penalty box. However, there were more outliers for big 6 teams, indicating that they received more red cards than bad 6 teams. Interestingly, the value for outliers in bad 6 teams was one, which implies that they directly received a red card when committing a foul.

It is crucial to note that the crowd is not the only factor that affects the ratio of yellow and red cards to fouls. For instance, the big 6 teams are generally at the top of the league standings, meaning that they are less likely to commit severe fouls that lead to cards. Therefore, further research is required to better understand the relationship between the crowd, team popularity, and the referees' decisions to issue cards.

**```{r red}**

This analysis visualizes the proportion of red cards per fouls committed by each home team using a bar graph.

The dataset `epl\_data` is first loaded and the variables of interest are mutated to compute the ratio of red cards given to home teams per home fouls committed. The data is then plotted using ggplot, with Home Team on the x-axis and the red card and foul ratio on the y-axis. The geom\_bar function is used to create a stacked bar graph, with the proportion of red cards and fouls are displayed in the y-axis

We can conclude from this bar graph that the proportion of red cards and fouls committed by each home team varies significantly. Some teams have a higher ratio of red cards per home fouls committed than other teams, indicating that they are more likely to receive red cards during a match. For example, Southampton have a ratio of around 0.825 while Tottenham have a ratio of a mere 0.0625. The bar graph shows a clear difference between the red card and foul ratios of different home teams.

The results of this analysis gives an insight into which home teams are more likely to receive red cards committed by fouls. However, we cannot conclude that having a high conversion ratio of red cards from fouls does not necessarily mean those teams lose more because Arsenal comes in 5th place for having the highest conversion ratio of red cards from fouls. A team that is consistently given more red cards from committing fouls than their opponents will, undoubtedly, face a disadvantage during the game, as they would be outnumbered. It is important to note that the proportion of receiving red cards from committed fouls does not impact the outcome of premier league matches to a great extent.

**```{r q3-graphs}**

This analysis uses three different bar charts to represent the average yellow cards, red cards, and fouls per match for every home team. The code starts with adding three columns to the `epl\_data` data frame: `fouls\_per\_game`, `yellow\_per\_game`, and `red\_per\_game`. These columns are created by grouping the data by HomeTeam and calculating the average number of fouls, yellow, and red cards per match. After adding these three new variables, three bar charts are created with the x-axis representing each home team and the y-axis representing the average number of fouls, yellow, and red cards per match.

The three charts show that different teams have varying levels of fouls, yellow, and red cards, which could impact the outcome of the game. We can observe from the graphs that some teams have a higher number of fouls and cards per game than other teams. However, we can observe that the average number of fouls and the average number of yellow cards booked by the home teams are generally similar to the rest of other teams but we can observe that Watford has the highest number average fouls (~12.5) and yellow cards (~2.25) from the recorded dataset. The last bar graph shows the average number of red cards per match for each team and we can observe that Huddersfield, Aston Villa, and Hull had the highest average number of red cards of around 0.125 red cards per game. However, unlike the previous two bar graphs, this bar graph shows that the number of red cards received per match is very different depending on the home teams. For example, although Tottenham commits an average of ~11 fouls per match and an average of ~1.4 yellow cards per match, they are only booked for red cards around 0.0125 times per match. However, we can notice that some of the Bad 6 teams have a low percentage of receiving red cards per game. Therefore, these three charts do not constitute the outcome of matches.

This result of the analysis suggests that the average number of fouls, yellow, and red cards given per match does not necessarily correlate with the outcome of premier league matches. Some teams commit more fouls, receive more yellow or red cards than other teams. Although the analysis does not allow us to confidently conclude that referees significantly impact the outcome of games, we can conclude that having a high percentage of receiving fouls, yellow, or red cards have a minuscule impact on the outcome of matches, as there are countless tactical fouls committed in a match.

**```{r q2-graphs: yellow cards}**

These series of bar charts show the average number of yellow cards per game for each referee and the teams they’ve refereed for, sorted by greatest to least. To perform this, we first created a new dataframe, card\_data, from epl\_data, which contained only our desired columns (HomeTeam, AwayTeam, Referee, HY, AY). Next, we divided each referee’s total number of cards given by the total number of games each of them refered for. A ggplot was then created, with the X-axis representing each team and the Y-axis representing the average yellow cards per game.

One notable bar chart includes R East’s, who gave on average of over 4 yellow cards per game to Wolverhampton Wanderers (Wolves) and Middlesbrough FC. In comparison, the 3rd highest was just over 2 yellow cards per game given to Aston Villa. Another interesting bar chart came from M Atkinson, who gave approximately 3 yellow cards per game to Queens Park Rangers, a noticeable amount more than the second most he gave to Bumley at less than 2.5 yellow cards. On the other side of the spectrum, referee L Mason gave Swansea an average of less than .5 yellow cards per game, which is much less than the 3 yellow cards per game they gave to Cardiff. However, when looking at the other referee’s bar graphs, in which most teams range between 1-2 yellow cards per game for all referees, based on this statistic alone, we cannot definitively conclude that all or even certain referees have a strong bias towards certain teams.

**```{r q2-graphs: red cards}**

Similarly with the yellow cards, these graphs depict the average number of red cards per game for each referee and the teams they’ve refereed for, sorted by greatest to least. The process of creating them is the same, with the exception of selecting HR and AR (home and away red cards) instead of HY and AY. The X-axis represents each team and the Y-axis represents the average red cards per game.

If we look at referee R East again, we observe that he gives roughly .5 red cards per game to Hull and .3 to Brighton and Huddersfield. In contrast with the yellow cards, they did not give any red cards to the Wolves or Middlesborough. One notable referee was M Atkinson, who gave Queens Park Rangers (QPR) the most yellow and red cards per game (~3 and ~.25, respectively) compared to the other teams they’ve refereed for.

**```{r q2-graphs: fouls }**

These bar graphs show the average number of fouls each referee calls per game for each team they’ve refereed for. The data frame was created using the same method as the yellow and red cards, except selecting for home fouls (HF) and away fouls (AF). The X-axis represents the teams, and the Y-axis represents the average number of fouls per game. It’s important to note that the number of red and yellow cards don’t necessarily add up to the total number of fouls per game, as players more often than not are simply given verbal warnings.

Looking at referee R East again, they called the most fouls on Middlesbrough (~15 per game), which is one of the two teams they gave the most yellow cards to on average. However, this didn’t necessarily correlate with the number of red cards they handed, as he never gave Middlesbrough a single red card over the 5 seasons. According to M Atkinson’s foul data, he called the second most fouls on QPR at over 10, which could possibly indicate a negative bias they have towards the team, when also considering the number of yellow and red cards they give to that team. When looking at the other referees however, there doesn’t seem to be a clear correlation between the average number of yellow and red cards and the number of fouls called for each team per game, as their results vary greatly.

**Q1 Stats.**

In order to answer the first research question, we separated the data into two groups, cards given to the home team and cards given to the away team. The total number of fouls, yellow cards, and red cards per game for each team was calculated. The number of games played by each team was calculated, and the average number of fouls, yellow cards, and red cards per game for each team was calculated. Finally, the data was separated into two groups, cards given to the Big 6 and cards given to the Bad 6.

The findings are as follows. The average number of fouls per game for the Big 6 was 10.4659. The z-score for the difference in the average number of fouls per game for the Big 6 and Bad 6 was -1.2814, which corresponds to a p-value of 0.2001. This indicates that the difference between the number of fouls per game for the Big 6 and Bad 6 teams in the EPL is not statistically significant at a significance level of 0.05.

The average number of yellow cards per game for the Big 6 was 1.6097, and for the Bad 6 was 1.8119. The z-score for the difference in the average number of yellow cards per game for the Big 6 and Bad 6 was -2.2133, which corresponds to a p-value of 0.0269. This indicates that there is a significant difference between the number of yellow cards per game for the Big 6 and Bad 6 teams in the EPL.

The average number of red cards per game for the Big 6 was 0.0583, and for the Bad 6 was 0.0533. The z-score for the difference in the average number of red cards per game for the Big 6 and Bad 6 was 0.3697, which corresponds to a p-value of 0.7116. This indicates that there is no significant difference between the number of red cards per game for the Big 6 and Bad 6 teams in the EPL.

The results show that there is a significant difference between the number of fouls and red cards per game for the Big 6 and Bad 6 teams in the EPL, but there is not a significant difference between the number of yellow cards per game for the Big 6 and Bad teams. However, since we cannot replicate this process with the other lower teams in the league, we cannot say this is significant.

**Limitations**

There are several possible lurking variables that could impact the study's findings on whether referees exhibit a home advantage bias in calling fouls in sports. For example, weather conditions can affect the playing conditions, which may lead to more fouls being committed. Similarly, rivalry matches may be more intense and emotionally charged, potentially causing players to commit more fouls and referees to make more disciplinary decisions. Therefore, these variables should be considered and accounted for in the analysis to ensure that the results are not skewed.

It's also important to note that the introduction of the Visual Assistant Referee (VAR) in the EPL after 2019 may have affected the results. Before VAR, referees had to make decisions subjectively, based on their interpretation of the events on the pitch. However, with VAR, there is a video review system that can help referees make more accurate decisions. This change in the refereeing process could have had an impact on the frequency and distribution of fouls and cards, and thus, should be considered when interpreting the study's results.

Furthermore, the study's findings may be limited by the sample size for certain teams. For example, teams that are frequently relegated or promoted to or from the EPL may not have enough data to draw meaningful conclusions about their disciplinary patterns. This could introduce bias into the analysis, and the results may not be representative of the broader population of EPL teams. Therefore, it's important to ensure that the sample size is large enough and that all teams are adequately represented to minimize potential biases and improve the generalizability of the findings.